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(54) **BIOLOGICAL PARTICLE ANALYZER AND METHOD OF ANALYZING BIOLOGICAL PARTICLES**

C12Q 2563/155; B01L 2400/0415; B01L 2200/027; B01L 3/502761; B01L 2200/0668; G01N 15/1459; G01N 15/1429; G01N 15/12; G01N 15/1404

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USPC 436/43; 422/73, 502; 435/288.7, 287.1; 210/748.05; 324/691

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See application file for complete search history.

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 134 days.

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(21) Appl. No.: **13/798,228**

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(30) **Foreign Application Priority Data**

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G01N 15/14 (2006.01)
G01N 33/49 (2006.01)
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H01J 49/00 (2006.01)
G01N 15/10 (2006.01)

(57) **ABSTRACT**

A biological particle analyzer is disclosed and includes a microchannel including an end coupled to a first drive electrode, another end coupled to a second drive electrode, a first detection area at an upstream location and an excitation area at a downstream location for containing particles flowing from the upstream location to the downstream location inside the microchannel, a first detection circuit coupled to the first detection area for outputting a first detection result when at least one particle has arrived at the first detection area, a light emission source, and a control module coupled to the first detection circuit and the light emission source for determining when to turn on or off the light emission source according to the first detection result.

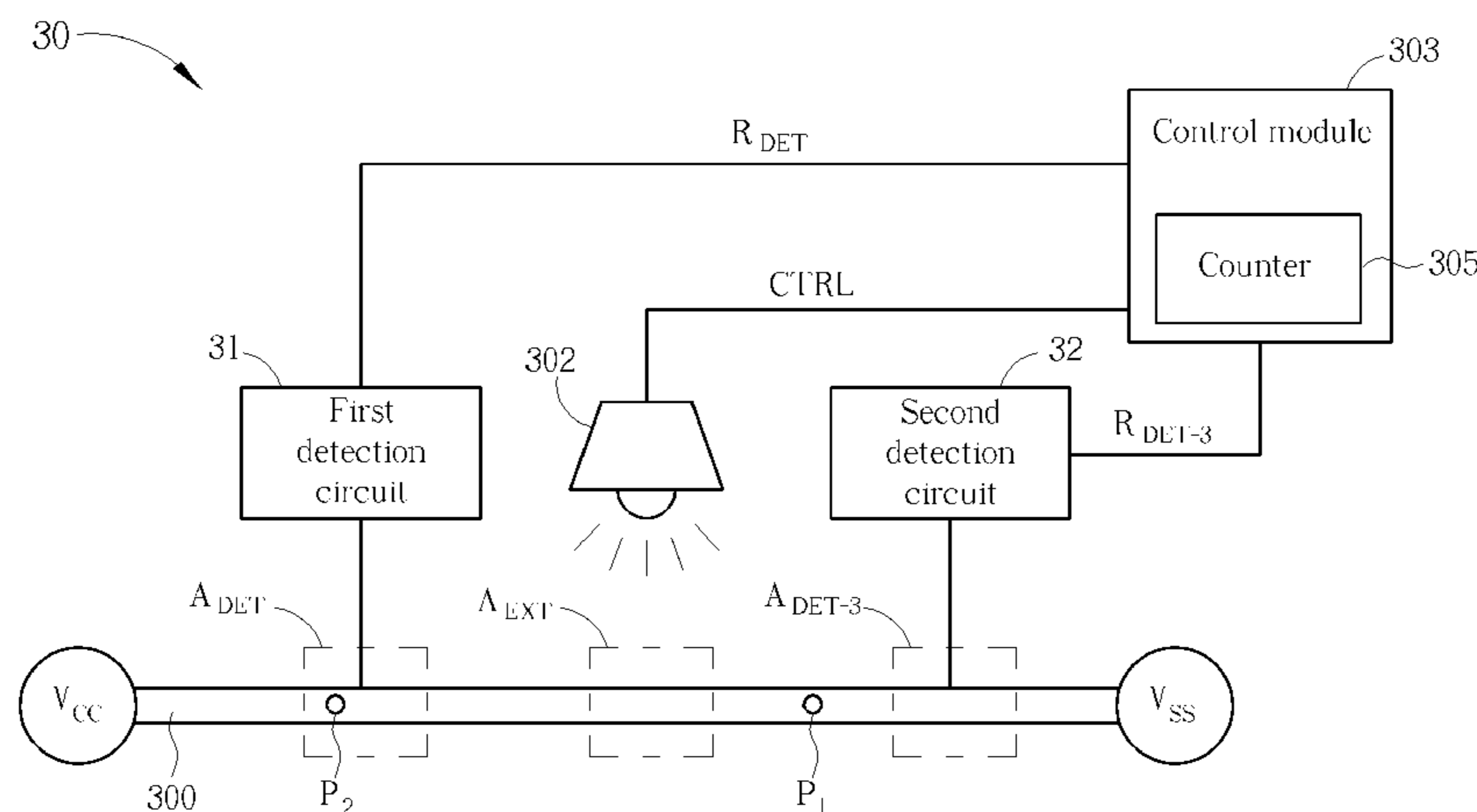
(52) **U.S. Cl.**

CPC **C12Q 1/02** (2013.01); **G01N 15/14** (2013.01); **G01N 15/1427** (2013.01); **G01N 33/4915** (2013.01); **B01L 2200/027** (2013.01); **G01N 2015/105** (2013.01); **G01N 2015/1037** (2013.01); **H01J 49/0027** (2013.01)

(58) **Field of Classification Search**

CPC C12Q 2565/629; C12Q 2563/149;

19 Claims, 8 Drawing Sheets



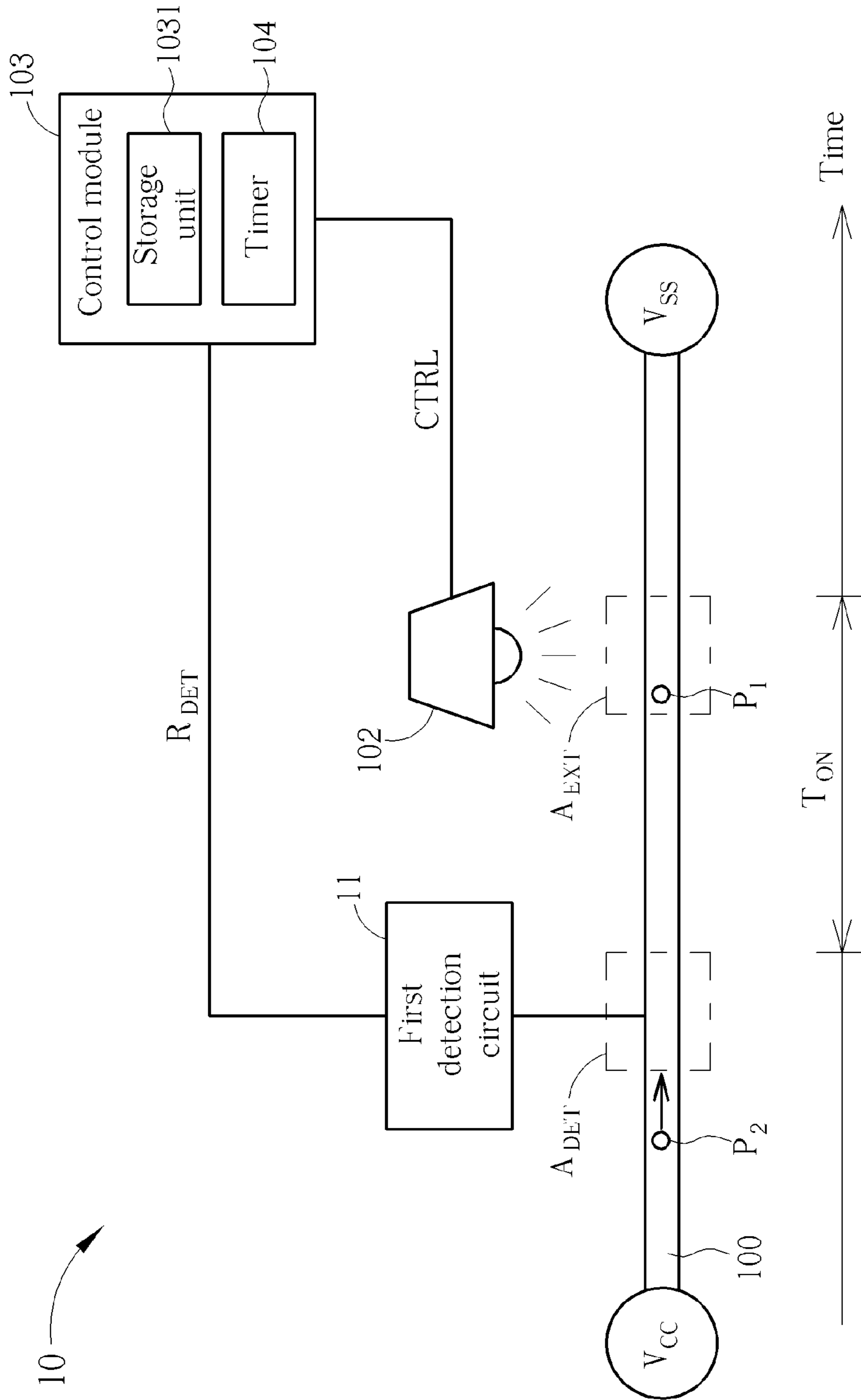


FIG. 1A

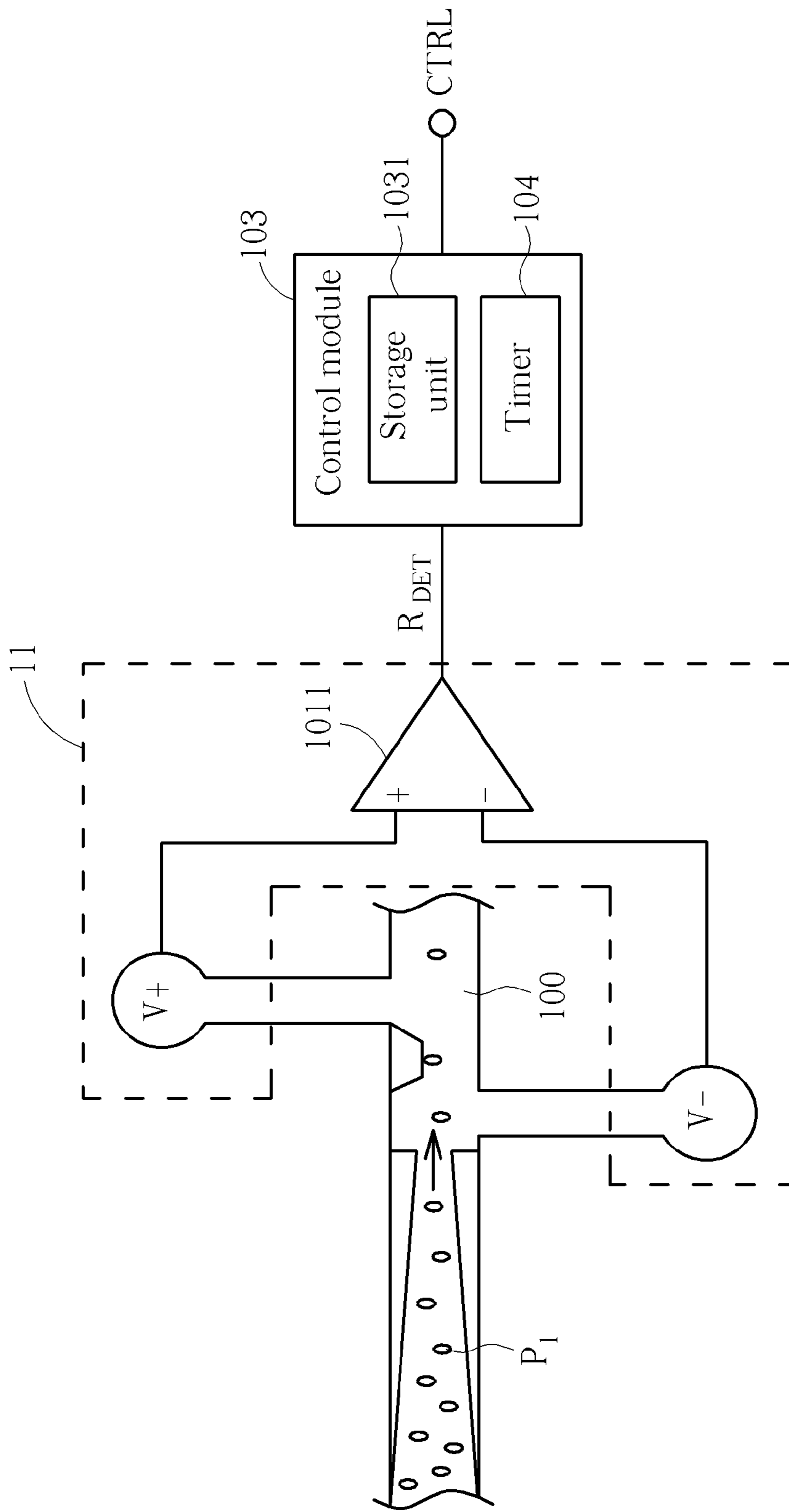


FIG. 1B

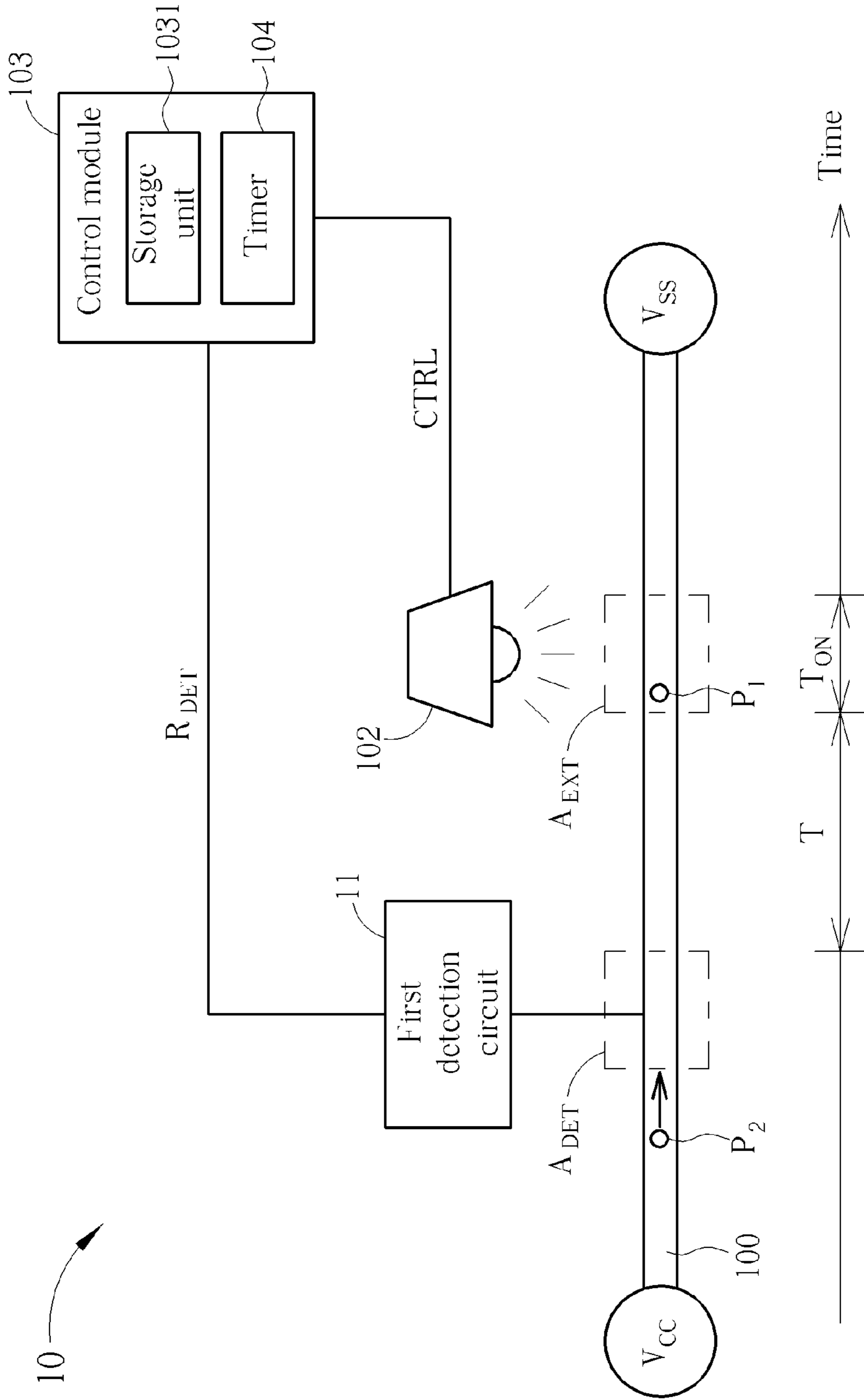


FIG. 1C

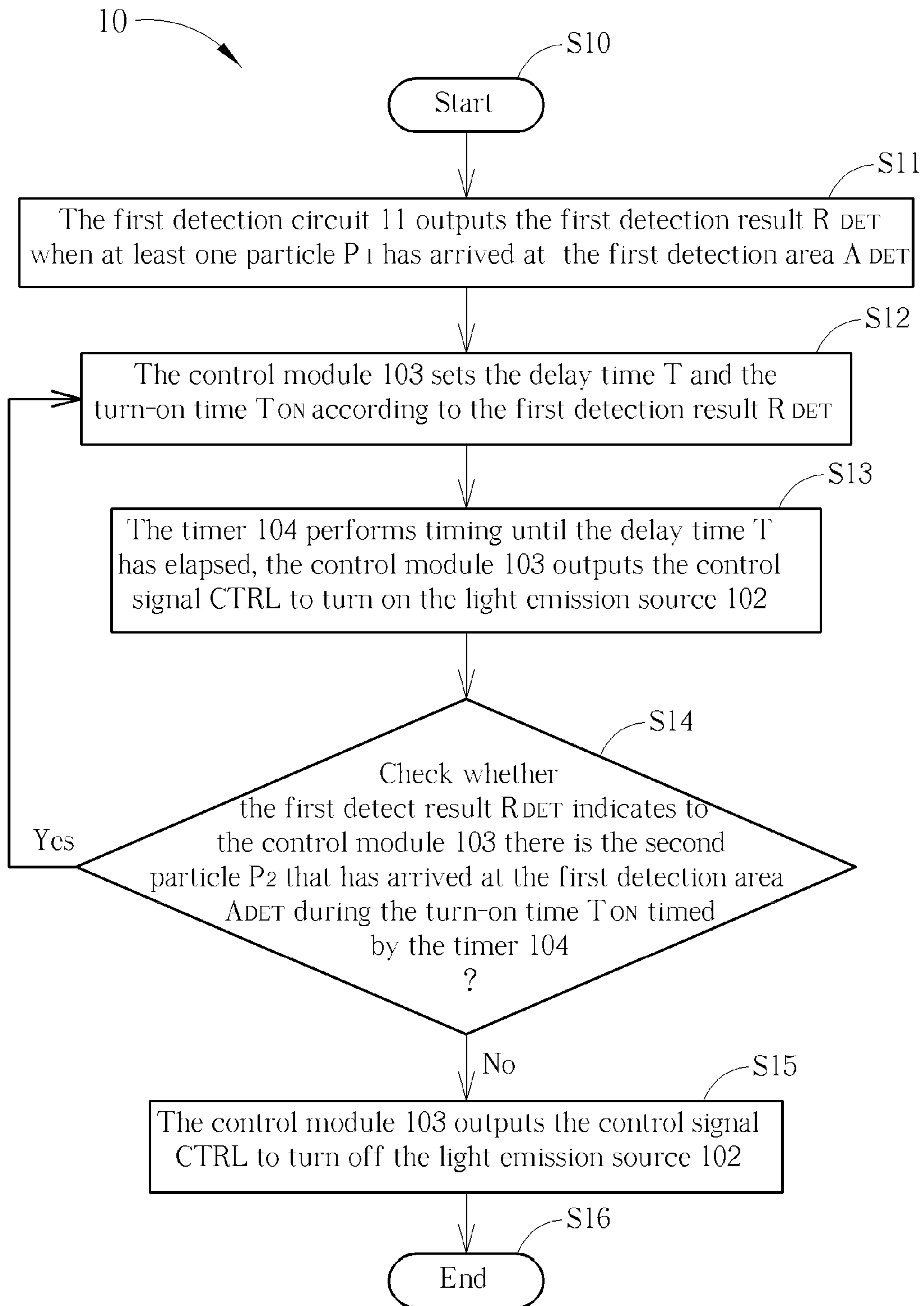


FIG. 1D

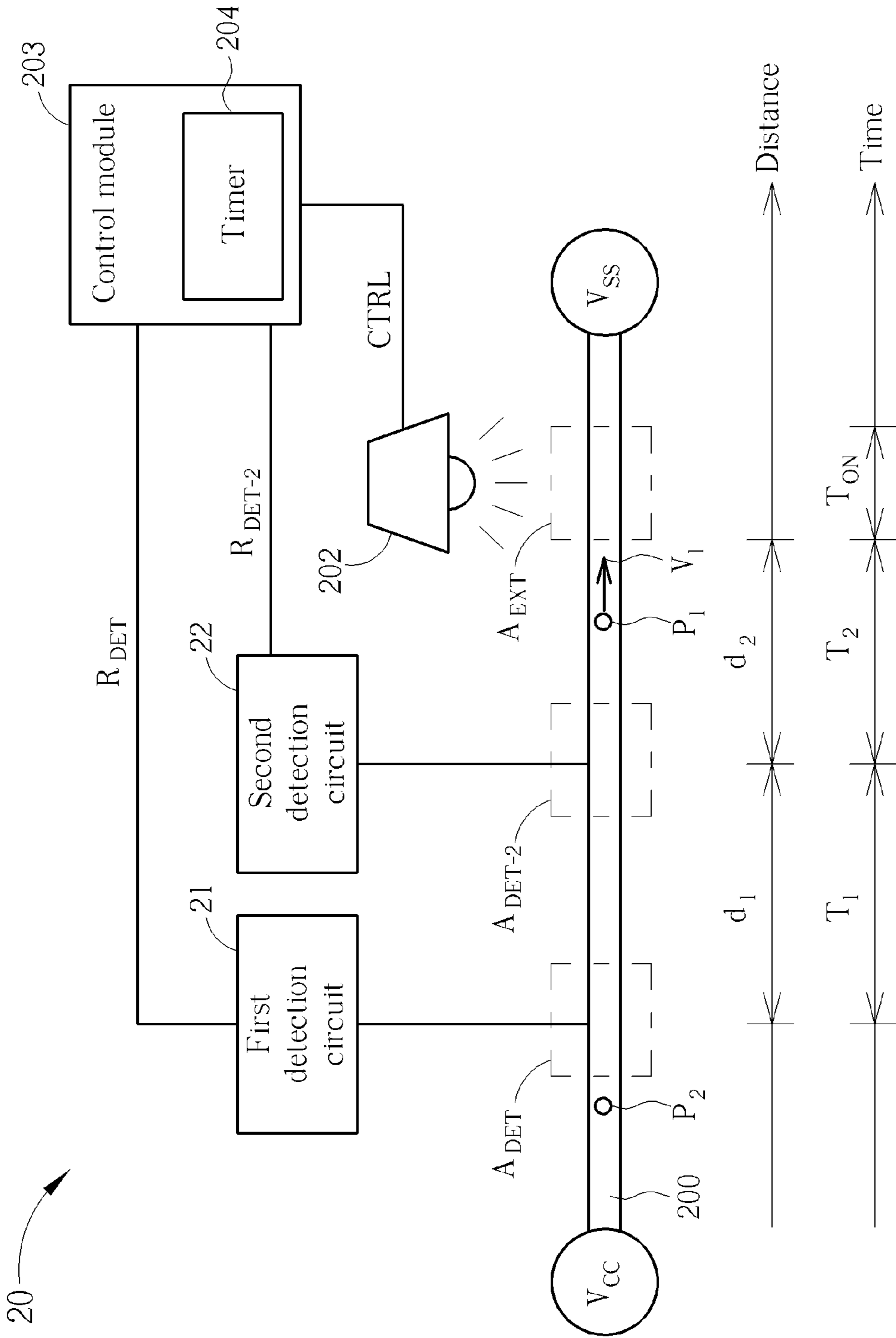


FIG. 2A

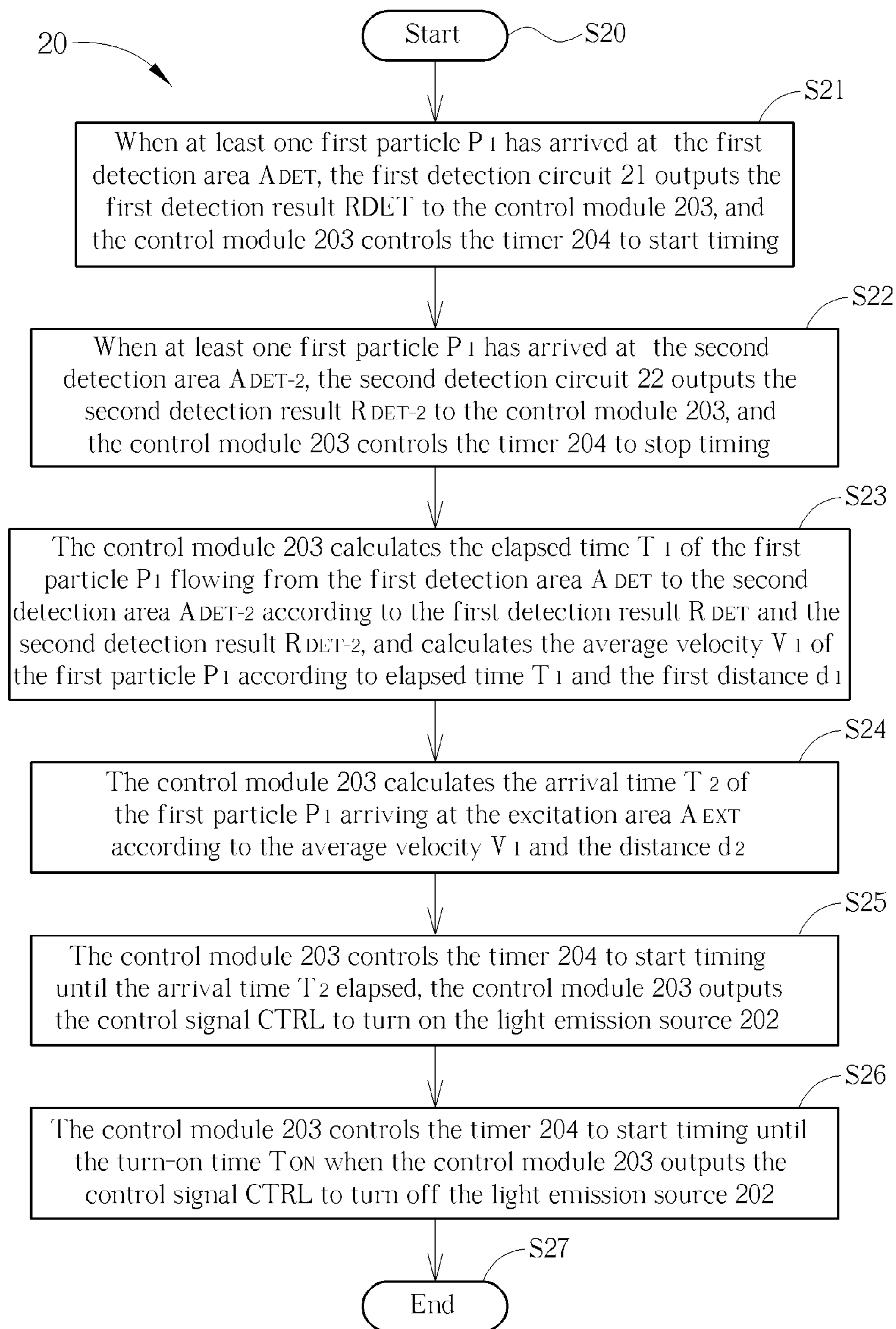


FIG. 2B

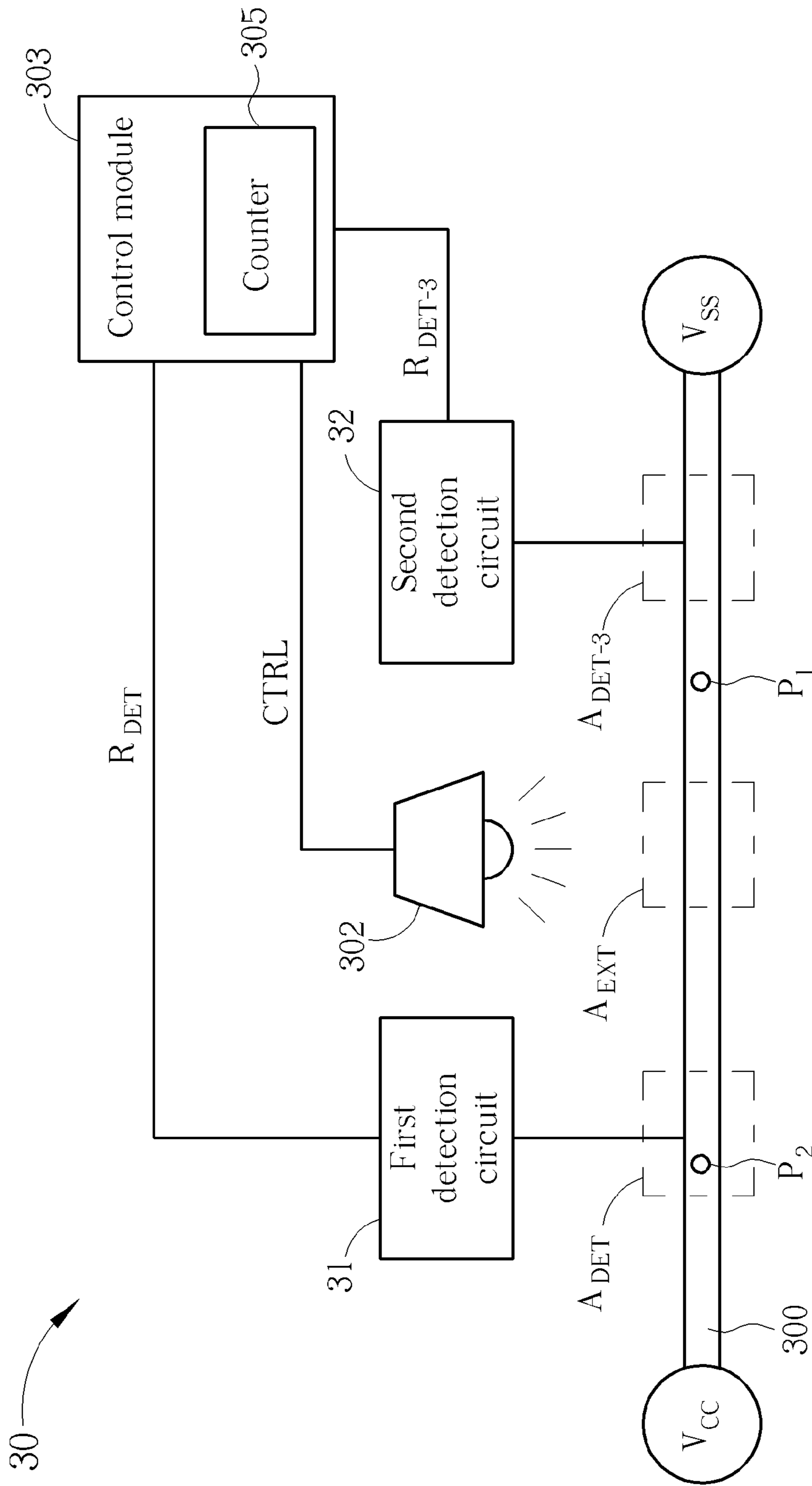


FIG. 3A

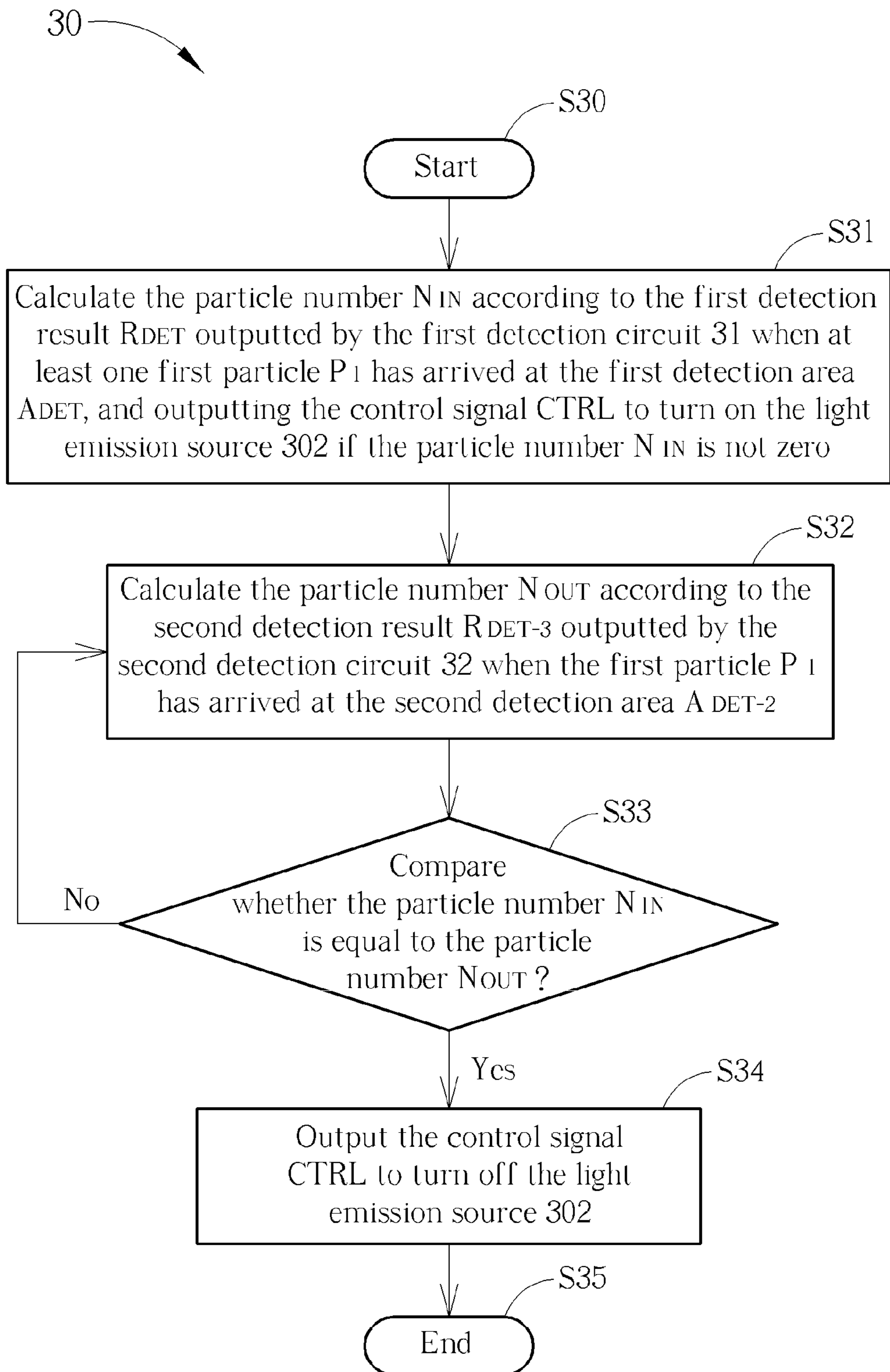


FIG. 3B

BIOLOGICAL PARTICLE ANALYZER AND METHOD OF ANALYZING BIOLOGICAL PARTICLES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a biological particle analyzer and method of analyzing biological particles, and more particularly, to a biological particle analyzer and method of analyzing biological particles having a function of smart power savings.

2. Description of the Prior Art

A biological particle analyzer is widely used in basic research and clinical practice for Biology related fields including Cell biology, Oncology, Hematology, Immunology, Pharmacology, Genetics and Diagnostics of Clinic Analysis. A Flow Cytometer is biophysical technology employed to perform simultaneously multiparametric analysis according to cell properties such as surface receptors and DNA by detecting scattered light from tested cells.

The Flow Cytometry utilizes a beam of laser light generated by a light emission source to directly light up the test cells, e.g. microparticles having a diameter 0.5~50 micrometers. Those cells attached to fluorescent chemicals are excited by the laser light to emit scatter lights, and the scatter lights are picked up by the electronic apparatus for quality and quantity analysis of the cells. Moreover, an advanced Flow Cytometer may perform sorting and selection to purify populations of interest cells to be reused for further application. Thus, the Flow Cytometer is widely used in experiments of Immunology, Microbiology and Cell biology.

In-Home Care or Telemedicine is becoming more and more popular nowadays as it helps people make simple health examinations, e.g. blood glucose measurements, in home or in distant rural communities. Thus, there is a need to design a portable Flow Cytometer.

However, when the traditional biological particle analyzer is operating, the light emission source of the biological particle analyzer or the Flow Cytometer consumes most of the power, and the light emission source is often turned on no matter whether a test procedure is being performed, which not only wastes power but also produces a significant amount of heat. For a portable Flow Cytometer, a battery having a high capacity is required, which increases a size/volume or production cost of the portable Flow Cytometer. Worse yet, the amount of heat may shorten battery life and influence usage convenience/reliability of the portable Flow Cytometer. Therefore, how to effectively reduce the power consumption of the light emission source and keep good performance of the portable Flow Cytometer has become a goal in the field.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a biological particle analyzer and method of analyzing biological particles having a function of smart power savings.

The present invention discloses a biological particle analyzer comprising a microchannel including an end coupled to a first drive electrode, another end coupled to a second drive electrode, a first detection area at an upstream location and an excitation area at a downstream location for containing particles to flow from the upstream location to the downstream location inside the microchannel, a first detection circuit coupled to the first detection area for outputting a first detection result when at least one particle has arrived at the first detection area, a light emission source for emitting a light to

the excitation area, and a control module coupled to the first detection circuit and the light emission source for determining when to turn on or off the light emission source according to the first detection result.

The present invention further discloses a method of analyzing biological particles for a biological particle analyzer comprising a light emission source and a microchannel for containing a particle flowing inside the microchannel, the microchannel comprising a first detection area at an upstream location and an excitation area at a downstream location lighted by the light emission source, the method comprising outputting a first detection result when at least one particle has arrived at the first detection area, and a control module outputting a control signal to turn on or off the light emission source according to the first detection result.

These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a schematic diagram of a biological particle analyzer according to a first embodiment of the present invention.

FIG. 1B is a schematic diagram illustrating an operational principle of the first detection circuit shown in FIG. 1A.

FIG. 1C is a schematic diagram of the biological particle analyzer shown in FIG. 1A according to a second embodiment of the present invention.

FIG. 1D is a schematic diagram of a biological particle analysis process according to the first and second embodiments of the present invention.

FIG. 2A is a schematic diagram of a biological particle analyzer according to a third embodiment of the present invention.

FIG. 2B is a schematic diagram of a biological particle analysis process according to the third embodiment of the present invention.

FIG. 3A is a schematic diagram of a biological particle analyzer according to a fourth embodiment of the present invention.

FIG. 3B is a schematic diagram of a biological particle analysis process according to the fourth embodiment of the present invention.

DETAILED DESCRIPTION

Please refer to FIG. 1A, which is a schematic diagram of a biological particle analyzer **10** according to a first embodiment of the present invention. The following description takes but not limited to a Flow Cytometer as an example of the biological particle analyzer **10**. The biological particle analyzer **10** comprises a microchannel **100**, a first detection circuit **11**, a light emission source **102** and a control module **103**. Two ends of the microchannel **100** are respectively coupled to drive electrodes V_{CC} and V_{SS} , the microchannel **100** is used for containing a plurality of particles P_1 to flow from an upstream location to a downstream location inside the microchannel **100**. The microchannel **100** comprises a first detection area A_{DET} and an excitation area A_{EXT} . The first detection circuit **11** is coupled to the first detection area A_{DET} for outputting a first detection result R_{DET} to the control module **103** when at least one particle P_1 has arrived at the first detection area A_{DET} . The control module **103** is coupled to the first detection circuit **11** and the light emission source **102** for

outputting a control signal CTRL to the light emission source **102** according to the first detection result R_{DET} , so as to control turning on or off the light emission source **102**. The light emission source **102** is coupled to the control module **103** for being turned on according to the control signal CTRL to emit a light to the excitation area A_{EXT} and the particle P_1 that has entered the excitation area A_{EXT} . The particle P_1 is attached to fluorescent chemicals and is excited by the light emission source **102** to emit scatter lights, such that the biological particle analyzer **10** may perform quality and quantity statistical analysis to the particle P_1 according to measurement results of the scatter lights attached by fluorescent chemicals.

Specifically, as soon as the first detection result R_{DET} indicates to the control module **103** that the particle P_1 has arrived at the first detection area A_{DET} , the control module **103** outputs the control signal CTRL to the light emission source **102** to turn on the light emission source **102**. The control module **103** performs timing by a built-in timer **104** to calculate a turn-on time T_{ON} of the light emission source **102**, to ensure the light emission source **102** is kept turned on during the predetermined turn-on time T_{ON} . When the turn-on time T_{ON} has elapsed, the control module **103** turns off the light emission source **102**. The turn-on time T_{ON} may be adjusted according to different characteristics of the particle P_1 , such as volume, electrical charges. As a result, the light emission source **102** is turned on only when the particle P_1 is being tested, i.e. turn-on time T_{ON} , which saves unnecessary power consumption.

In short, the biological particle analyzer **10** may be notified that the particle P_1 is about to pass the excitation area A_{EXT} by the first detection circuit **11** detecting the arrival of the detection area A_{DET} , such that the control module **103** turns on the light emission source **102** accordingly. When the turn-on time T_{ON} has elapsed, the control module **103** turns off the light emission source **102**. Therefore, the light emission source **102** is turned on only when the particle P_1 is being tested, such that the biological particle analyzer **10** may automatically control the turn-on time T_{ON} of the light emission source **102** to achieve smart power savings.

Besides, if the first detection circuit **11** detects another particle P_2 has arrived at the detection area A_{DET} during the turn-on time T_{ON} of the light emission source **102**, the control module **103** may reset the timer **104** and generate a new turn-on time T_{ON} according to the newly received first detection result R_{DET} , such that the light emission source **102** is kept turned on during the new turn-on time T_{ON} to light up the excitation area A_{EXT} . As a result, the biological particle analyzer **10** may automatically adjust the turn-on time T_{ON} of the light emission source **102** during the test procedure of the particles, which save unnecessary power consumption.

Noticeably, FIG. 1A illustrates one of the embodiments of the present invention, those skilled in the art may make proper modifications and not limited to this embodiment. For example, as well known in the art, the biological particle analyzer **10** works based on Electrokinetics, two ends of the microchannel **100** may be applied drive voltages having opposite polarities according to a electrically charged polarity of the particle P_1 , a uniform directed electric field may be formed inside the microchannel **100**, and the electrically charged particle P_1 may be attracted by the electric field to flow inside the microchannel **100**, which is called Electrophoresis of an electrically charged particle. If the particle P_1 is positive electrically charged, the drive electrode V_{CC} is applied to a positive drive voltage, and the drive electrode V_{SS} is applied to a negative drive voltage. On the contrary, if the particle P_1 is negative electrically charged, the drive electrode

V_{CC} is applied to a negative drive voltage, and drive electrode V_{SS} is applied to a positive drive voltage. The first detection circuit **11** is preferably a Resistive Pulse Sensor.

Please refer to FIG. 1B, which illustrates an operational principle of the first detection circuit **11**. As shown in FIG. 1B, the first detection circuit **11** may be a differential amplifier **1011** including a positive input terminal $V+$ and a negative input terminal $V-$ coupled to the first detection area A_{DET} and an output terminal for outputting the first detection result R_{DET} . A diameter of the microchannel **100** is narrower as the particle P_1 flows closer to the first detection area A_{DET} , which may align the particles flowing through the microchannel **100** into a serial stream. That is, the first detection area A_{DET} may be passed by the sole single particle P_1 . Before the particle P_1 arrives at the first detection area A_{DET} , a voltage difference between the positive input terminal $V+$ and the negative input terminal $V-$ is a constant. When the particle P_1 is passing the first detection area A_{DET} , the voltage difference between the positive input terminal $V+$ and the negative input terminal $V-$ is influenced by an electrical charge of the particle P_1 to have a voltage variation, and the differential amplifier **1011** may amplify the voltage variation of the voltage difference to generate the first detection result R_{DET} , which is an impulse signal, to the control module **103**. In other words, when the particle P_1 is passing the first detection area A_{DET} , a resistance of the first detection area A_{DET} is changed, such that the first detection circuit **11** is capable of detecting the existence of the particle P_1 to output the first detection result R_{DET} .

Therefore, the first detection circuit **11** may output different impulse signals, i.e. the first detection result R_{DET} to the control module **103** according to different particle characteristics of the particle P_1 , such as volume, electrical charge quantity and so on. The control module **103** may further comprise a storage unit **1031** for storing the first detection result R_{DET} and the turn-on time T_{ON} corresponding to different particle characteristics, such that the control module **103** may select the turn-on time T_{ON} of the light emission source **102** accordingly. As a result, the biological particle analyzer **10** may precisely control the turn-on time T_{ON} of the light emission source **102** according to different particle characteristics.

The first embodiment describes the light emission source **102** being turned on by the turn-on time T_{ON} as soon as the particle P_1 has arrived at the first detection area A_{DET} . In the second embodiment of present invention, as shown in FIG. 1C, a difference between the first embodiment and the second embodiment is that there is a delay time T after the particle P_1 has arrived at the first detection area A_{DET} and the light emission source **102** is turned on after the delay time T is elapsed. Specifically, the control module **103** may set the delay time T counted by the timer **104**, the light emission source **102** is turned on for the predetermined turn-on time T_{ON} when the delay time T elapsed and the particle P_1 is going to arrive at the excitation area A_{EXT} . The storage unit **1031** may store the delay time T and the turn-on time T_{ON} according to different particle characteristics, and the timer **104** may time the delay time T and the turn-on time T_{ON} , which allows the biological particle analyzer **10** to automatically turn on or off the light emission source **102**.

Operations of the biological particle analyzer **10** in the first and second embodiments may be summarized into a biological particle analysis process P10, as shown in FIG. 1D. The biological particle analysis process P10 comprises the following steps:

Step S10: Start.

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Step S11: The first detection circuit **11** outputs the first detection result R_{DET} when at least one particle P_1 has arrived at the first detection area A_{DET} .

Step S12: The control module **103** sets the delay time T and the turn-on time T_{ON} according to the first detection result R_{DET} .

Step S13: The timer **104** performs timing until the delay time T has elapsed, the control module **103** outputs the control signal CTRL to turn on the light emission source **102**.

Step S14: Check whether the first detect result R_{DET} indicates to the control module **103** there is the second particle P_2 that has arrived at the first detection area A_{DET} during the turn-on time T_{ON} timed by the timer **104**, if yes, go to Step S12; if no, go to Step S15.

Step S15: The control module **103** outputs the control signal CTRL to turn off the light emission source **102**.

Step S16: End.

Please note that the steps S10-S15 of the biological particle analysis process P10 are used for the biological particle analyzer **10** shown in FIG. 1C. For the biological particle analyzer **10** shown in FIG. 1A, steps S12 and S13 for setting the delay time T may be omitted, which may be regarded as the delay time T is zero, i.e. $T=0$. Details of the biological particle analysis process P10 may be obtained by referring to descriptions of the biological particle analyzer **10**, which is omitted herein.

Furthermore, an average velocity of the particle P_1 flowing in the microchannel may be calculated to obtain an arrival time of the particle P_1 arriving at the excitation area A_{EXT} , so as to more precisely determine the turn-on time T_{ON} for turning on the light emission source **102**. For example, please refer to FIG. 2A, which is a schematic diagram of a biological particle analyzer **20** according to a third embodiment of the present invention. The biological particle analyzer **20** comprises a microchannel **200**, a first detection circuit **21**, a second detection circuit **22**, a control module **203**, a timer **204** and drive electrodes V_{CC} and V_{SS} . The first detection circuit **21** is coupled to a first detection area A_{DET} close to the drive electrode V_{CC} of the microchannel **200**, the first detection circuit **21** is used for outputting a first detection result R_{DET} to the control module **203**. The second detection circuit **22** is coupled to a second detection area A_{DET-2} between a downstream location of the first detection area A_{DET} and the excitation area A_{EXT} of the microchannel **20**. The second detection circuit **22** is used for outputting a second detection result R_{DET-2} to the control module **203**.

As shown in FIG. 2A, the second detection area A_{DET-2} is located between the first detection area A_{DET} and the excitation area A_{EXT} . There is a distance d_1 between the second detection area A_{DET-2} and the first detection area A_{DET} and a distance d_2 between the second detection area A_{DET-2} and the excitation area A_{EXT} . When the particle P_1 sequentially arrives at the first detection area A_{DET} and the second detection area A_{DET-2} /the first detection circuit **21** and the second detection circuit **22** respectively outputs the first detection result R_{DET} and the second detection result R_{DET-2} to the control module **203**. The control module **203** may calculate an elapsed time T_1 of the particle P_1 flowing from the first detection area A_{DET} to the second detection area A_{DET-2} according to the first detection result R_{DET} and the second detection result R_{DET-2} . The control module **203** may also calculate an average velocity V_1 of the particle P_1 according to the elapsed time T_1 and the distance d_1 . Specifically, the timer **204** starts timing as soon as the control module **203** receives the first detection result R_{DET} , and the timer **204** stops timing when the control module **203** receives the second detection result R_{DET-2} , wherein the elapsed time T_1 is the time that the

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particle P_1 flowing from the first detection area A_{DET} to the second detection area A_{DET-2} . As a result, the control module **203** may calculate the average velocity V_1 of the particle P_1 according to elapsed time T_1 and distance d_1 , i.e. $V_1=d_1/T_1$. Then, the control module **203** may calculate an arrival time T_2 of the particle P_1 arriving at the excitation area A_{EXT} according to the average velocity V_1 and the distance d_2 , i.e. $T_2=V_1/d_2$, so that the control module **203** may output the control signal CTRL to turn on the light emission source **202** at the arrival time T_2 and keep the light emission source **202** turned on during the turn-on time T_{ON} .

Similar to the first embodiment, if the first detection circuit **21** detects another particle P_2 has arrived at the detection area A_{DET} before the light emission source **202** is turned off, i.e. during the turn-on time T_{ON} , the control module **203** may recalculate the arrival time T_2 and extend the turn-on time T_{ON} of the light emission source **202** until the particle P_2 has left the excitation area A_{EXT} according to the latest received first detection result R_{DET} and the second detection result R_{DET-2} . Noticeably, in practice, the biological particle analyzer **20** may test a plurality of particles at the same time, a designer may adjust the turn-on time T_{ON} to turn on light emission source **202** according to numbers of the plurality of particles. For example, there are at least two cases that may happen when two or more particles P_1 and P_2 are tested at the same test process.

Case (1): The particle P_1 is in the excitation area A_{EXT} , which means the light emission source **202** is turned on during the turn-on time T_{ON} , and the particle P_2 has left the first detection area A_{DET} but has not arrived at the second detection area A_{DET-2} . When case (1) happens, although the turn-on time T_{ON} has elapsed, the control module **203** preferably keeps the light emission source **202** turned on until the particle P_2 has arrived at the second detection area A_{DET-2} . Accordingly the control module **203** may calculate a new arrival time T_2 and a new turn-on time T_{ON} to reset the timer **204**, and thus the light emission source **202** is kept turned on around (T_2+T_{ON}) until the particle P_2 is finished testing. If the arrival time T_2 of the particle P_2 arriving at the excitation area A_{EXT} is too short, e.g. a velocity of the particle P_2 is fast, such that the control module **203** may be too late to turn on the light emission source **202**, which may cause the light emission source **202** to be turned on and off quickly in a short time, in order to protect the light emission source **202** and related circuits, the control module **203** preferably keeps the light emission source **202** turned on until the particle P_2 is finished testing. Therefore, in case (1), a real turn-on time of the light emission source **202** for testing the particles P_1 and P_2 may be different according to particle characteristics, flowing velocity or locations flowing to the first detection area A_{DET} and the second detection area A_{DET-2} .

On the other hand, case (2): The particle P_1 remains in the excitation area A_{EXT} , which means the light emission source **202** is turned on during the turn-on time T_{ON} , and the particle P_2 has arrived at the second detection area A_{DET-2} , the control module **203** recalculates a new arrival time T_2 and a new turn-on time T_{ON} . When case (2) happens, the control module **203** may set a new arrival time T_2 and a new turn-on time T_{ON} and reset the timer **204** to keep the light emission source **202** turned on around (T_2+T_{ON}) , until the particle P_2 is finished testing. In case (2), the real turn-on times of the light emission source **202** corresponding to the test procedures of the particles P_1 and P_2 may be different since the particles P_1 and P_2 may be distinct and have different properties and velocities or locations passing the excitation area A_{EXT} .

As a result, the biological particle analyzer **20** may automatically turn on or off the light emission source **102** during

the test procedure to save power consumption or prevent fast power switching. Furthermore, besides turning on the light emission source **202** during the turn-on time T_{ON} when the particles P_1 and P_2 are passing the excitation area A_{EXT} , a designer may adjust a time that the light emission source **202** is turned on according to practical test conditions to have a flexible control time for turning on and off the light emission source **202**.

Operations of the biological particle analyzer **20** in the third embodiment may be summarized into a biological particle analysis process **P20**, as shown in FIG. **2B**. The biological particle analysis process **P20** comprises the following steps:

Step **S20**: Start.

Step **S21**: When at least one first particle P_1 has arrived at the first detection area A_{DET} , the first detection circuit **21** outputs the first detection result R_{DET} to the control module **203**, and the control module **203** controls the timer **204** to start timing.

Step **S22**: When at least one first particle P_1 has arrived at the second detection area A_{DET-2} , the second detection circuit **22** outputs the second detection result R_{DET-2} to the control module **203**, and the control module **203** controls the timer **204** to stop timing.

Step **S23**: The control module **203** calculates the elapsed time T_1 of the first particle P_1 flowing from the first detection area A_{DET} to the second detection area A_{DET-2} according to the first detection result R_{DET} and the second detection result R_{DET-2} , and calculates the average velocity V_1 of the first particle P_1 according to elapsed time T_1 and the first distance d_1 .

Step **S24**: The control module **203** calculates the arrival time T_2 of the first particle P_1 arriving at the excitation area A_{EXT} according to the average velocity V_1 and the distance d_2 .

Step **S25**: The control module **203** controls the timer **204** to start timing until the arrival time T_2 elapsed, the control module **203** outputs the control signal CTRL to turn on the light emission source **202**.

Step **S26**: The control module **203** controls the timer **204** to start timing until the turn-on time T_{ON} when the control module **203** outputs the control signal CTRL to turn off the light emission source **202**.

Step **S27**: End.

Details of the biological particle analysis process **P20** may be obtained by referring to descriptions of the biological particle analyzer **20**, which is omitted herein.

Furthermore, the second detection circuit **22** shown in FIG. **2A** may be disposed close to the drive electrode V_{SS} in the microchannel **200** to have another method to determine when to turn on the light emission source **102**. Please refer to FIG. **3A**, which is a schematic diagram of a biological particle analyzer **30** according to a fourth embodiment of the present invention. As shown in FIG. **3A**, a first detection circuit **31** of the biological particle analyzer **30** is coupled to the first detection area A_{DET} close to the drive electrode V_{CC} in the microchannel **300**, the first detection circuit **31** is used for outputting the first detection result R_{DET} to control module **303**. The second detection circuit **32** is coupled to a detection area A_{DET-3} at a downstream of the excitation area A_{EXT} in the microchannel **300**, i.e. the excitation area A_{EXT} is located between the first detection area A_{DET} and the second detection area A_{DET-3} .

In such a structure, when the particle P_1 has arrived at the first detection area A_{DET} , the first detection circuit **31** may output the first detection result R_{DET} to the control module **303**. The control module **303** may output the control signal CTRL to the light emission source **302** to turn on the light

emission source **302**. When the particle P_1 has arrived at the second detection area A_{DET-3} , the second detection circuit **32** may output the second detection result R_{DET-3} to the control module **303**, such that the control module **303** may output the control signal CTRL to the light emission source **302** to turn off the light emission source **302**.

Noticeably, the control module **303** may further comprise a counter **305** for respectively counting particle numbers N_{IN} and N_{OUT} when at least one particle has arrived at the first detection area A_{DET} and the second detection area A_{DET-3} , so as to determine to turn on or off the light emission source **302**. Specifically, when the particle P_1 is about to flow in the microchannel **300**, the counter **305** defaulted the particle numbers N_{IN} and N_{OUT} to be zero, the detection circuit **301** may detect the particle P_1 has arrived at the first detection area A_{DET} and output the first detection result R_{DET} to the control module **303**. The control module **303** increases the particle number N_{IN} of the counter **305** by 1, and outputs the control signal CTRL to the light emission source **302** to turn on light emission source **302**. When the particle P_1 sequentially arrives at the excitation area A_{EXT} and the second detection area A_{DET-3} , which means the particle P_1 has been fully tested, the second detection circuit **32** may output the second detection result R_{DET-3} to the control module **303**, and control module **303** may increase the particle number N_{OUT} of the counter **305** by 1. Therefore, when the particle number N_{IN} is equal to the particle number N_{OUT} , i.e. $N_{IN}=N_{OUT}$, the control module **303** may confirm the particle P_1 has been fully tested, after which, the control module **303** may output the control signal CTRL to the light emission source **302** to turn off light emission source **302**.

For example, when test two or more of the particles P_1 and P_2 , the control module **303** may count the particle number N_{IN} to be 2 to turn on the light emission source **302** according to the first detection result R_{DET} outputted by the first detection circuit **31**. Then, the control module **303** counts the particle number N_{OUT} to be 2 according to the second detection result R_{DET-3} outputted by the second detection circuit **32**, and outputs the control signal CTRL to the light emission source **302** to turn off the light emission source **302**. As a result, the control module **303** may respectively record that the particle numbers N_{IN} and N_{OUT} indicated the particles have arrived at the first detection area A_{DET} and the second detection area A_{DET-3} , so as to determine to turn on or off the light emission source **302**, which allows the biological particle analyzer **30** to automatically turn on or off the light emission source **302** during the test procedure to reduce power consumption.

Operations of the biological particle analyzer **30** may be summarized into a biological particle analysis process **P30**, as shown in FIG. **3B**. The biological particle analysis process **P30** comprises the following steps:

Step **S30**: Start.

Step **S31**: Calculate the particle number N_{IN} according to the first detection result R_{DET} outputted by the first detection circuit **31** when at least one first particle P_1 has arrived at the first detection area A_{DET} , and outputting the control signal CTRL to turn on the light emission source **302** if the particle number N_{IN} is not zero.

Step **S32**: Calculate the particle number N_{OUT} according to the second detection result R_{DET-3} outputted by the second detection circuit **32** when the first particle P_1 has arrived at the second detection area A_{DET-3} .

Step **S33**: Compare whether the particle number N_{IN} is equal to the particle number N_{OUT} , if yes, go to Step **S34**; if no, go to Step **S32**.

Step S34: Output the control signal CTRL to turn off the light emission source 302.

Step S35: End.

Details of the biological particle analysis process P30 may be obtained by referring to descriptions of the biological particle analyzer 30, which is omitted herein.

Please note that the timer described in the above mentioned embodiments is built into the control module, which is not limiting, those skilled in the art may realized that the timer may be integrated in other circuits or devices of the biological particle analyzer, as long as the timer may be controlled by the control module to perform counting time and/or clocking.

To sum up, when the traditional biological particle analyzer is operating, the light emission source for emitting a light to the particles consumes most of power of the biological particle analyzer, and the light emission source is often turned on no matter whether a test procedure is being performed, which not only wastes power but also produces a significant amount of heat. The significant amount of heat may reduce battery life, influence usage convenience, deteriorate product reliability and increase production costs. In comparison, the biological particle analyzers 10, 20 and 30 of the present invention may have different detection methods or judgment parameters, such as setting the turn-on time of the light emission source, calculating the average velocity of the particle to evaluate the arrival time of the particle arriving at the light emission source, or calculating the number of the particles to determine to turn on or off the light emission source. Thus, the biological particle analyzers 10, 20 and 30 may automatically turn on or off the light emission source to save unnecessary power consumption, which achieves smart power savings. As a result, the biological particle analyzers 10, 20 and 30 of the present invention may effectively reduce power consumption, extend battery life and increase product reliability, or reduce a volume of a battery, which reduces a size and production cost of the biological particle analyzer and also facilitates a birth of a miniature biological particle analyzer.

Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

What is claimed is:

1. A biological particle analyzer comprising:

a microchannel including an end coupled to a first drive electrode, another end coupled to a second drive electrode, a first detection area at an upstream location and an excitation area at a downstream location for containing particles to flow from the upstream location to the down stream location inside the microchannel;

a first detection circuit coupled to the first detection area for outputting a first detection result when at least one particle has arrived at the first detection area;

a light emission source for emitting a light to the excitation area;

a second detection circuit coupled to a second detection area located at a downstream location of the first detection area inside the microchannel for outputting a second detection result to the control module when the particles have arrived at the second detection area; and

a control module coupled to the first detection circuit, the second detection circuit and the light emission source for determining when to turn on or off the light emission source according to the first detection result to save power consumption of the light emission source;

wherein the control module is configured to calculate a turn-on time according to different particle characteris-

tics and an average velocity of the at least one particle, and the light emission source is turned on only when the at least one particle is being tested during the turn-on time;

wherein when the first detection result indicates that a first particle of the at least one particle has arrived at the first detection area, the control module outputs the control signal to the light emission source to turn on the light emission source, and when the second detection result indicates that the first particle has arrived at the second detection area, the control module outputs the control signal to the light emission source to turn off the light emission source;

wherein the control module further comprises a counter for recording a first particle number when the first particle of the at least one particle has arrived at the first detection area and a second particle number when the first particle of the at least one particle has arrived at the second detection area to determine to turn on or off the light emission source.

2. The biological particle analyzer of claim 1, wherein the control module further comprises a timer.

3. The biological particle analyzer of claim 2, wherein when the first detection result indicates a first particle has arrived at the first detection area, the control module outputs a control signal to turn on the light emission source for the turn-on time timed by the timer.

4. The biological particle analyzer of claim 3, wherein when the first detection result indicates a second particle has arrived at the first detection area during the turn-on time that the light emission source is turned on, a new turn-on time is reset by the timer so that the light emission source keeps lighting up the excitation area during the new turn-on time.

5. The biological particle analyzer of claim 2, wherein when the first detection result indicates a first particle has arrived at the first detection area, the control module sets a delay time counted by the timer, and outputs a control signal to turn on the light emission source after the delay time elapsed, such that the light emission source lights up the excitation area for the turn-on time timed by the timer.

6. The biological particle analyzer of claim 1, wherein the first detection circuit is a Resistive Pulse Sensor.

7. The biological particle analyzer of claim 6, wherein the first drive electrode is applied to a positive drive voltage and the second drive electrode is applied to a negative drive voltage if the particle is positive electrically charged.

8. The biological particle analyzer of claim 6, wherein the first drive electrode is applied to a negative drive voltage and the second drive electrode is applied to a positive drive voltage if the particle is negative electrically charged.

9. The biological particle analyzer of claim 1, wherein the control module further comprises a storage unit for storing the detection result corresponding to the different particle characteristics to accordingly set the turn-on time and a turn-off time of the light emission source.

10. The biological particle analyzer of claim 1, wherein the second detection area is located between the first detection area and the excitation area, there is a first distance between the first detection area and the second detection area, and a second distance between the second detection area and the excitation area.

11. The biological particle analyzer of claim 10, wherein the control module calculates an elapsed time of the particle flowing from the first detection area to the second detection area according to the first detection result and the second detection result, and calculates the average velocity of the particle according to the elapsed time and the first distance.

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12. The biological particle analyzer of claim **11**, wherein the control module comprises a timer, the timer starts timing as soon as the control module receives the first detection result, and the timer stops timing when the control module receives the second detection result, wherein the elapsed time is the time that the particle flowing from the first detection area to the second detection area.

13. The biological particle analyzer of claim **11**, wherein the control module calculates an arrival time according to the average velocity of the particle and the second distance, such that the control module outputs the control signal to the light emission source to turn on the light emission source for lighting up the excitation area during the turn-on time after the arrival time elapsed.

14. The biological particle analyzer of claim **13**, wherein when a first particle has arrived at the excitation area within the turn-on time, and the first detection result indicates a second particle has arrived at the first detection area, the control module extends the turn-on time of the light emission source until the second particle has arrived at the second detection area to generate the second detection result, the control module resets a new arrival time and a new turn-on time, such that the light emission source is turned on during

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the new arrival time and the new turn-on time until the second particle has arrived at the excitation area.

15. The biological particle analyzer of claim **13**, wherein when a first particle has arrived at the excitation area within the turn-on time, and the second detection result indicates a second particle has arrived at the second detection area, the control module resets a new arrival time and a new turn-on time, such that the light emission source is turned on during the new arrival time and the new turn-on time until the second particle arrived at the excitation area.

16. The biological particle analyzer of claim **1**, wherein the excitation area is located between the first detection area and the second detection area.

17. The biological particle analyzer of claim **1**, wherein if the first particle number is not zero, the control module outputs the control signal to the light emission source to turn on the light emission source.

18. The biological particle analyzer of claim **1**, wherein if the second particle number is equal to the first particle number, the control module outputs the control signal to the light emission source to turn off the light emission source.

19. The biological particle analyzer of claim **1**, wherein the biological particle analyzer is a Flow Cytometer.

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